

**Evaluation of the potential of cultured mussels
(*Mytilus edulis*) to ingest stage I lobster
(*Homarus americanus*) larvae**

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ABSTRACT

Gendron, L., A.M. Weise, M. Fréchette, P. Ouellet, C.W. McKindsey and L. Girard. 2003. Evaluation of the potential of cultured mussels (*Mytilus edulis*) to ingest stage I lobster (*Homarus americanus*) larvae. Can. Ind. Rep. Fish. Aquat. Sci. 274: vii + 20 p.

In Quebec, mussel aquaculture is expanding rapidly and is being developed in areas where lobster is present and where lobster larvae are likely to be found. Lobster fishermen are concerned that mussel aquaculture could pose a threat to lobster larvae. They believe that cultured mussels may ingest or otherwise kill lobster larvae. The objective of this study was to evaluate the potential of cultured mussels (*Mytilus edulis*) to ingest stage I lobster (*Homarus americanus*) larvae and, if this does occur, determine whether this ingestion kills or otherwise harms the larvae. In a first series of experiments, larvae were placed with mussel sleeve sections in 30-L buckets. Since very few larvae came into contact with the mussels, a second series of experiments was conducted in a more confined area (4 L beakers), forcing the larvae to interact with the mussels. This experiment allowed us to describe five types of behaviour. The frequency of each type of behaviour was evaluated during a third series of experiments using a video camera. Our results show that lobster larvae do not approach mussels when placed in a large enclosure. In a more confined area, the larvae swim freely around the mussels and are not caught up by the inhalant current created by the mussels. The most frequent behaviours recorded during two trials were larvae swimming around the mussels (66%-74%), larvae touching the mussels' mantle, followed by the mantle closing and the larvae swimming away from the mussel apparently unharmed (18%-27%), and larvae touching the mussels' shell without any reaction from the mussel (5%-7%). Occasionally (1%) a larva was imprisoned in the mussel for several seconds but was able to escape, apparently unharmed once the mussel re-opened. On only two occasions (< 1%), larvae were not seen again after having entered the mussels. This occurred at the end of trials when the larvae were less active. From our observations, it is reasonable to believe that ingestion of lobster larvae by mussels does not constitute a threat for lobster populations.

RÉSUMÉ

Gendron, L., A.M. Weise, M. Fréchette, P. Ouellet, C.W. McKindsey and L. Girard.
2003. Evaluation of the potential of cultured mussels (*Mytilus edulis*) to ingest stage I lobster (*Homarus americanus*) larvae. Can. Ind. Rep. Fish. Aquat. Sci. 274: vii + 20 p.

Au Québec, la mytiliculture est en plein essor et se développe présentement dans des secteurs où le homard est présent et où il est probable de retrouver des larves de homard. Les pêcheurs de homard s'interrogent à savoir si la mytiliculture peut représenter un danger pour les larves de homard. Ils évoquent la possibilité que les moules puissent ingérer les larves de homard et causer leur mort. L'objectif de ce projet était d'évaluer si les larves de homard (*Homarus americanus*) de stade I sont capturées par les moules d'élevage (*Mytilus edulis*) lorsque placés ensemble et de déterminer, le cas échéant, si cette ingestion pouvait tuer ou blesser la larve. Dans une première série d'expériences, des larves ont été mises en présence de sections de boudins de moules dans des seaux de 30 L. Puisque très peu de larves sont entrées en contact avec les moules, nous avons mené une deuxième série d'expériences en milieu restreint (bêchers de 4 L), forçant alors les larves à entrer en contact avec les moules. Cette expérience a permis de décrire 5 types de comportements dont la fréquence d'occurrence a été évaluée à partir d'images vidéo tournées lors d'une troisième série d'expériences. Les résultats montrent que lorsque l'espace n'est pas restreint, les larves de homard ne vont pas sur les moules. En milieu restreint, les larves nagent librement autour des moules et ne sont pas entraînées par leur courant inhalant. Les comportements les plus fréquents observés au cours de deux séries d'observations étaient la nage libre de la larve sans contact avec la moule (66%-74%), le contact de la larve avec le manteau de la moule suivi par la fermeture du manteau et de la fuite de la larve (18%-27%), et le contact de la moule avec la paroi extérieure des coquilles de la moule sans réaction de la part de la moule (5%-7%). Occasionnellement (1%), des larves ont été emprisonnées pendant quelques secondes dans le manteau de la moule mais elles ont pu s'échapper par la suite. Ces larves semblaient intactes. Il n'y a qu'en deux occasions seulement (<1%) que des larves ayant pénétré à l'intérieur d'une moule n'ont pas été vues en ressortir. Ceci s'est produit à la fin des expériences alors que les larves semblaient moins actives. Selon nos observations, rien n'indique que l'ingestion des larves de homard par les moules peut constituer un danger pour les populations de homard.



1.0 INTRODUCTION

Aquaculture of the blue mussel (*Mytilus edulis*) is expanding rapidly in Quebec. Annual production increased from an average of 121 tons for the period 1996-1999 to 234 tons in 2000 and 492 tons in 2001 (Government of Quebec 2002). Moreover, production is expected to reach 2000 tons within the next few years (Government of Quebec 2002). Mussel aquaculture is developing in coastal areas where lobster is present, and where lobster larvae are likely to be found in the water column. Lobster fishermen are concerned that mussel aquaculture could pose a threat to lobster larvae. They believe that mussels may ingest or otherwise kill lobster larvae.

Mussels are filter feeders and rely on suspended particles in the water column as food. Seawater is drawn in through the inhalant siphon (Figure 1) and then filtered by the gills. After the particles have been sorted, the food retained by the mussel is transferred to the digestive system by the labial palps, passes through the oesophagus and into the stomach where the food is digested. The undigested material moves through the intestine to the anus and is expelled through the exhalant siphon. When the particles are too large to be retained by the gills or ingested, or when they are too concentrated, they are amalgamated together with mucus by the labial palps to form pseudofaeces, which are rejected through the exhalant siphon.

(a)



(b)

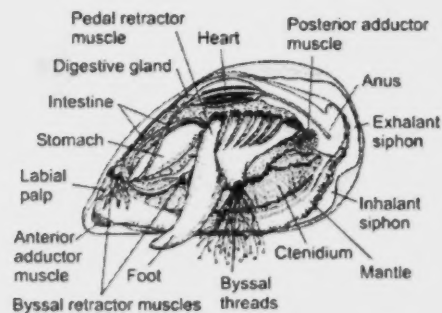


Figure 1. The (a) external and (b) internal anatomy of a mussel (from Meyer and Möbius 1872 and <http://biodidac.bio.uottawa.ca/>).

Mussels filter and ingest a variety of suspended particles, including phytoplankton, bacteria, detritus and microzooplankton (Bayne and Newell 1983, Griffiths and Griffiths 1987, Horsted *et al.* 1988, Jones *et al.* 1990, Jørgensen 1991, Norén *et al.* 1999). Although previous studies have noted the presence of animal fragments in the stomachs or faeces of bivalves (Cowden *et al.* 1984, Nelson 1933, Savage 1925, referenced in Lehane and Davenport 2002), bivalves are generally considered as herbivores. However, recent laboratory and field studies demonstrated that benthic and zooplanktonic organisms may also be ingested by *M. edulis* (Davenport *et al.* 2000, Lehane and Davenport 2002). These studies indicated that both 300 μm *Artemia* sp. nauplii and 1-1.2 mm copepods could be ingested by 30-35 mm mussels. Moreover, copepods (< 1.5 mm), crab zoeas (2 mm), fish eggs (1-2 mm), and amphipods (5-6 mm) were also found in the stomachs of mussels of this size. Stage I lobster larvae however are slightly larger than the above-mentioned organisms. They measure approximately 8 mm at hatching and reach 9.5 mm at stage II (Factor 1995). At mussel culture sites in Quebec, mussels are larger than those used in the above-mentioned experiments, often reaching 70 mm at harvest. It is reasonable to believe that mussels of this size can consume or kill mesozooplankton, and potentially modify the local recruitment of benthic organisms and fish.

In light of the observations on the ingestion of mesozooplankton by mussels made by Davenport *et al.* (2000) and Lehane and Davenport (2002), and in order to address the concerns expressed by lobster fishermen, we wanted to evaluate the ability of mussels to ingest or otherwise harm or kill stage I lobster larvae. The study also aimed to describe, using video images, the behaviour of mussels and lobster larvae when placed together.

2.0 MATERIAL AND METHODS

2.1 LOBSTER LARVAE

Lobster (*Homarus americanus*) larvae used in the experiments were obtained from six berried females harvested off the Magdalen Islands on July 8, 2002, by a commercial fisherman. The selected females were small (average carapace length, CL of 79 mm) and carried orange-coloured eggs containing embryos that were visible to the naked eye. Upon their arrival at the Maurice Lamontagne Institute (MLI), the females were placed individually in 60-L Kreisel basins (Figure 2a) at a temperature of approximately 15°C, compared to 13°C in their natural environment. The females were fed every two days with thawed, chopped shrimp.

Two females began releasing larvae the day after their arrival. All females began releasing larvae within 6 days thereafter. In general, all larvae from a given female were released over an approximately six-day period. Only stage I larvae, less than 24 hours old, were used for the experiments. At 15°C, the duration of stage I is approximately 5 days (see review by Ennis 1995). Larvae were collected at least one hour after being fed (100,000 *Artemia* sp. per 60-L Kreisel basin, for approximately 1,000 to 3,000 larvae). This ration is greater than the suggested optimal ration of 4 *Artemia* sp. per larvae per day (Carlberg and Van Olst 1976). The average size of the stage I larvae varied from 1.95 to 1.98 mm (CL), depending on the female. This size corresponds to an overall length of approximately 8.0 mm (Figure 2b).

(a)



(b)



Figure 2. (a) A female lobster and lobster larvae in a 60-L Kreisel basin, and (b) a stage I lobster larva.

2.2 MUSSELS

The mussels (mainly *M. edulis*) used for the experiments were acquired from mussel growers from the Magdalen Islands (experiments 1, 2, and 3) and from Carleton (experiment 3). Market-ready sleeves were transported to the MLI by plane from the Magdalen Islands and by car from Carleton. For experiment 1, four mussel sleeve sections weighing approximately 575 g (fresh weight) each and containing between 65 and 79 mussels were used (Table 1). Between 20 and 25 mussels measured > 50 mm in the sleeve sections used, representing > 90% of the total weight. For the dead mussel controls (see the experiment description below), sleeve sections were frozen at -40°C and thawed in seawater (10-15°C) one hour before the beginning of the experiments. Once thawed, they were transferred to the experimental buckets. Details of these sleeves are given in Table 1. For experiment 2, we used four sleeve sections weighing approximately 785 g, with an average of 72 mussels, 26 of which were longer than 50 mm, and represented between 84% and 90% of the total weight of the sleeve sections (Table 2). For experiment 3, we selected only individual mussels measuring more than 70 mm.

Table 1. Characteristics of the mussels used in experiment 1.

Live mussels				
	Series 1		Series 2	
Bucket	1	2	1	2
Total number of mussels	65	68	79	72
Sleeve weight (g) (only mussels)	586,3	573,3	572,4	563,6
<i>Mussels ≥ 50 mm</i>				
Number	23	21	25	20
Average length (mm)	63,3	66,4	64,2	65,9
Maximum length (mm)	73,7	75,7	70,0	66,7
Average weight (g)	22,6	25,2	21,6	25,5
Maximum weight (g)	36,6	39,2	32,9	34,2
Dead mussels				
	Series 1		Series 2	
Bucket	1	2	1	2
Total number of mussels	79	72	77	62
<i>Mussels ≥ 50 mm</i>				
Number	26	28	26	21
Average length (mm)	63,3	60,6	61,2	64,4
Maximum length (mm)	70,0	66,7	69,8	72,0

Each mussel sleeve section measured approximately 15 cm in length and 12 cm in diameter (38 cm to 40 cm circumference).

Table 2. Characteristics of the mussels used in experiment 2.

	Trial 1	Trial 2	Trial 3	Trial 4
Total number of mussels	30*	74	65	76
Total weight (g)	677,4*	840,5	744,6	777,7
<i>Mussels ≥ 50 mm</i>				
Number	26	26	26	26
Average length (mm)	66,7	66,5	62,8	62,6
Maximum length (mm)	72,3	76,6	72,0	70,7
Average weight (g)	26,7	23,8	25,9	26,1
Maximum weight (g)	38,5	40,4	40,1	34,3

Each mussel sleeve section measured approximately 15 cm in length and 12 cm in diameter (38 cm to 40 cm circumference).

* The weight and length measurements for mussels measuring less than 20 mm are missing for the first trial.

2.3 DESCRIPTION OF THE EXPERIMENTS

Experiment 1: Interactions in a semi-confined space

In the first experiment, lobster larvae were placed in the presence of mussels in a relatively open environment where larvae were free to move and able to avoid the mussels if required. Mussel sleeve sections, approximately 15 cm in length and 12 cm in diameter, were immersed in 30-L buckets of 25 cm diameter (Figure 3). Seawater was collected close to the surface from the MLI wharf the morning of the experiments and filtered through a 100 μ m screen to remove large particles. To acclimatize the mussels and incite them to filter, the sleeves were immersed in seawater for at least 1 hour before the start of the experiments. The sleeves were then transferred to new buckets containing filtered seawater ($15 \pm 0.5^\circ\text{C}$) at the start of each experiment. The set-up consisted of two buckets containing one live mussel sleeve section each, two buckets containing one dead mussel sleeve section each, and two buckets containing only seawater. Two types of controls were used. The buckets containing dead mussels were used to evaluate the impact of the physical structure of the sleeve on the larvae. The second control, the buckets without mussels, was used to determine the mortality rate of larvae due to experimental conditions other than the presence of mussels. Magnetic stirrers were used to ensure that the water remained mixed throughout the experiments. The stirrers were placed at the bottom of the buckets under vexar baskets. Thirty larvae were added to each bucket. The distribution of the larvae in the water column as well as the behaviour of mussels and larvae were observed for one hour. The experiment was done twice, each time using larvae from a different female. At the end the 60-minute period, all larvae were collected and observed in order to determine their status (alive, dead, or wounded) and verify whether they were coated in mucus. Since no contact occurred between the larvae and the mussels, this experiment was terminated before the planned 4 replicates

were done. A second experiment was set-up in a more confined space with a protocol designed to highlight some general trends.

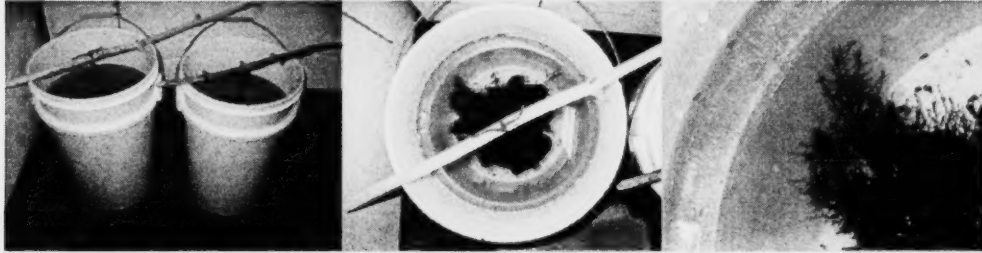


Figure 3. Experimental set-up to evaluate the interactions between lobster larvae and mussels in a semi-confined space (experiment 1).

2.3.2 Experiment 2: Interactions in a confined space

Due to the absence of contact between larvae and mussels in experiment 1 (see section 3.1), a second experiment was carried out in a more confined environment, where lobster larvae were forced to be in contact with mussels. Live mussel sleeve sections were placed in 4-L beakers. The edges of the sleeve touched the sides of the beaker, and the level of water in the beaker was approximately 5 cm above the top of the sleeve (Figure 4). A magnetic stirrer under a vexar basket on the bottom of the beaker was used to ensure that the water remained mixed throughout the experiment. Thirty larvae were added to the beakers, and the behaviour of mussels and larvae was observed during 30 minutes. The experiment was done four times, with larvae from each of two different females being used twice. At the end of the experiments, lobster larvae were collected, counted, and as in experiment 1, their physical status was noted.



Figure 4. Experimental set-up to evaluate the interactions between lobster larvae and mussels in a confined space (experiment 2).

2.3.3 Experiment 3: Evaluation of the frequency of interactions using video images

Video sequences (Sony DCR-TRV210 Digital 8 Camera) were recorded in order to describe and quantify the frequency of the various behaviours of mussels and larvae that had been observed in the first two experiments. Nine mussels > 70 mm long were placed in a vexar basket in a 1.5-L beaker to which thirty larvae were added (Figure 5). A magnetic stirrer, placed under a second vexar basket, ensured that the water remained mixed during the experiment. The mussels were positioned so that their inhalant and exhalant siphons were readily visible. During the first video sequence, with mussels from Carleton, a single mussel was filmed for 20 minutes until lobster larvae showed signs of weakness. During the second video sequence, this time with mussels from the Magdalen Islands, a single mussel was filmed for 30 minutes. The video images were first viewed in order to note the variety of mussel and lobster larvae behaviours. The images were then re-examined to quantify the frequency of each behaviour. Each new larva that appeared on the screen was observed, and its behaviours noted until it left the screen. Observations on several larvae could be made simultaneously.

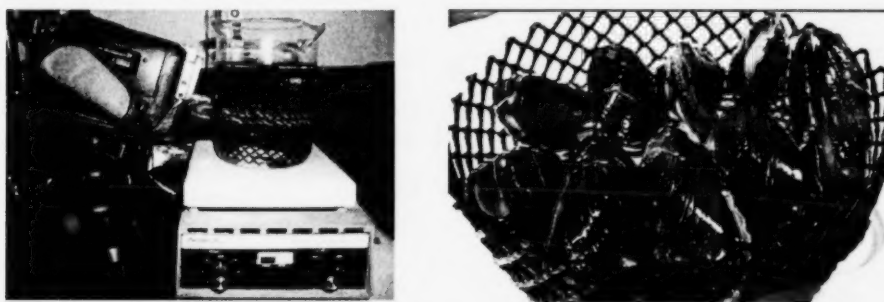


Figure 5. Experimental set-up to evaluate the frequency of interactions between lobster larvae and mussels using a video camera (experiment 3).

2.4. FLUORESCENCE MEASUREMENTS

Fluorescence measurements were made throughout the experiments in order to confirm the filtration activity of the mussels. In the first experiment, three 1.2 mL samples were collected from each bucket at 10-minute intervals. Each sample was placed in 6.8 mL of acetone for 24 hours and then centrifuged to extract the chlorophyll. Fluorescence measurements were made with a fluorometer according to the method outlined by Phinney and Yentsch (1985). In the second experiment, samples were collected every 5 minutes. No fluorescence measurements were made during the third experiment. Visual examination of the mussels, i.e. siphon extension, confirmed that the mussels were filtering.

3.0 RESULTS

3.1 EXPERIMENT 1. INTERACTIONS IN A SEMI-CONFINED SPACE

In the presence of mussels, dead or living, the lobster larvae were mostly distributed along the bucket walls. In the buckets without mussels, the larvae were distributed more homogeneously in the water column. No contact between larvae and mussels was observed during the 60 minutes of the experiment. The results from the second series of mussel sleeves and larvae from another female were similar (Figure 6). After 20 minutes in the presence of mussels, nearly 85% of larvae were distributed along the bucket walls, mainly near the surface (Figure 6a). Only 15 to 20% were observed in the water column, and these were near the surface. Larvae with dead mussel sleeves were also mostly distributed along the bucket walls (Figure 6b). In buckets without mussels, larvae were more evenly distributed in the water column (around 50 to 60% were found in the water column, Figure 6c). The distribution of larvae after 60 minutes was similar to that observed after 20 minutes. As in the first series, no contact with mussels was observed during the experiment. Although these observations may suggest that lobster larvae actively avoided the mussels, our observations made during the following experiments do not support this idea. Their preponderance on the walls of buckets with mussel sleeves may partly result from differences in currents created by the magnetic stirrer due to the mussel sleeves themselves.

Fluorescence measurements made throughout the experiment (series 1 and 2) confirmed that mussels were filtering. Fluorescence, which is an indicator of phytoplankton concentration, decreased from 20.6 units at the beginning of the experiment to 7.4 units at the end of the experiment, a reduction of 64% for series 1 (Figure 7a). In buckets containing dead or no mussels, the fluorescence remained constant throughout the experiment (Figures 7b and 7c). Similar results were observed in the second series of trials, even though an increase in fluorescence was evident ten minutes after the beginning of the experiment in one of the two buckets. This increase could be due to the presence of sediments or pseudofaeces in the water that could have been re-suspended by the magnetic stirrer.

During series 1, several larvae died (1 in a bucket containing live mussels, 3 in a bucket with dead mussels and 2 and 7 in the two buckets without mussels, respectively). This was likely because larvae came into contact with the magnetic stirrer at the bottom of the buckets. All lobster larvae recovered at the end of the second series were alive and vigorous.

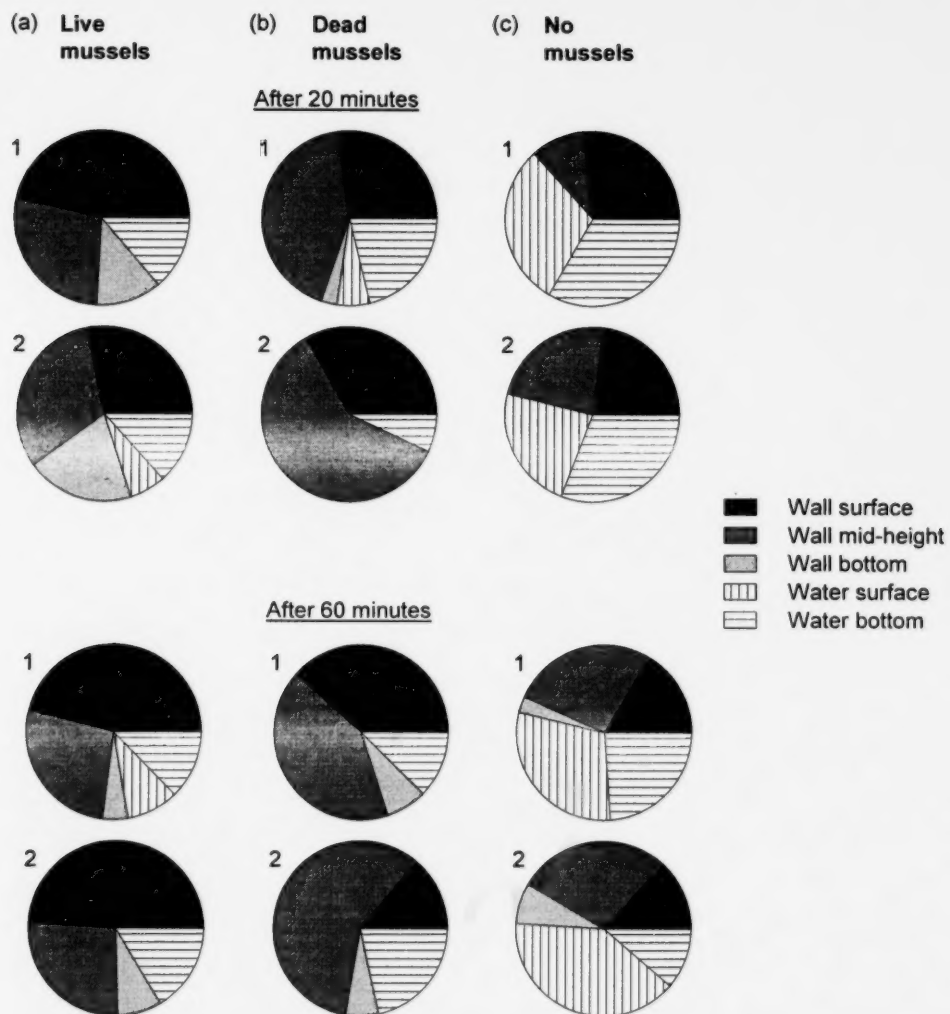


Figure 6. Distribution of lobster larvae after 20 and 60 minutes in each bucket containing (a) a live mussel sleeve section, (b) a dead mussel sleeve section, and (c) no mussels. Data from the second series of experiment 1. The buckets for each treatment are numbered 1 and 2.

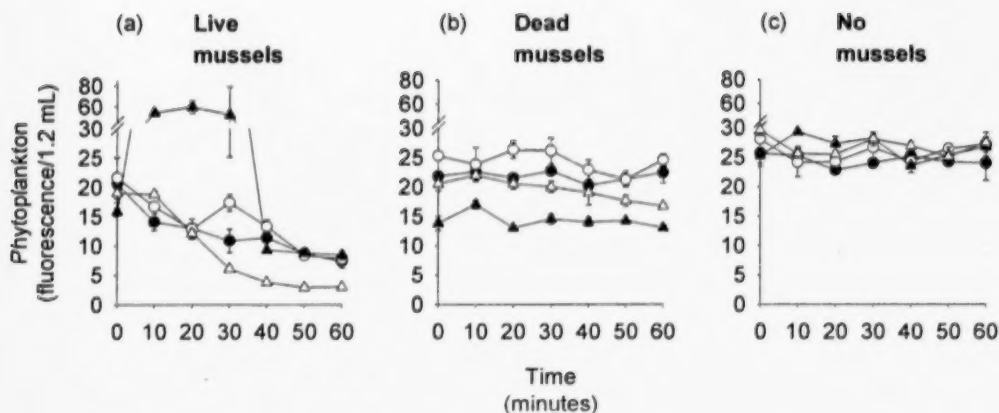


Figure 7. Phytoplankton concentration (fluorescence·1.2 mL⁻¹) in each bucket containing: (a) a live mussel sleeve section, (b) a dead mussel sleeve section, and (c) no mussels. The symbols refer to the series and bucket: series 1, bucket 1 (black circle); series 1, bucket 2 (white circle); series 2, bucket 1 (black triangle); series 2, bucket 2 (white triangle). Vertical bars indicate the standard deviation around the mean of the three measures of fluorescence.

3.2 EXPERIMENT 2. INTERACTIONS IN A CONFINED SPACE

At the end of each of the four series of experiments carried out in a confined space, 29, 30, 28, and 29 of the 30 larvae used in each series were recovered, respectively. The sleeves were taken apart to recover any larvae caught between mussels. Three larvae died in the third series, possibly because of contacts with the magnetic stirrer at the bottom of the beaker (unrecorded personal observations). Dead larvae did not seem to have been taken in by the mussels (*i.e.*, they were not coated in mucus). The larvae not accounted for were likely taken in, either actively or passively, by the mussels. The mussels were not dissected to find them.

Mussel filtration was confirmed by fluorescence measurements (Figure 8). The levels measured in the first series of observations were outside of the range of the fluorometer at times T5 and T10, possibly for the same reasons as those mentioned above (section 3.1). However, between time T15 and T20, the fluorescence decreased by 18%. The fluorescence decreased by 86%, 76% and 88% between the beginning and the end of the experiments of series 2, 3, and 4, respectively, indicating that the mussels were filtering.

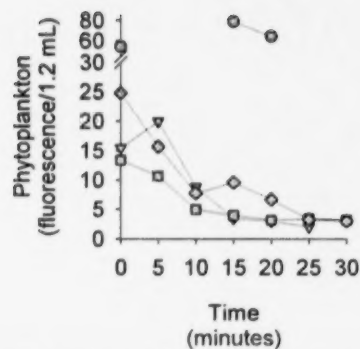


Figure 8. Phytoplankton concentration (fluorescence · 1.2 mL⁻¹) in each beaker in experiment 2.

3.3. EXPERIMENT 3. EVALUATION OF THE FREQUENCY OF INTERACTIONS USING VIDEO IMAGES

The various types of behaviour observed between lobster larvae and mussels are illustrated in Figure 9. In the first video sequence, a total of 166 interactions were noted between lobster larvae and a mussel from Carleton over a 20-minute period. The most frequent behaviour (66% of the observations) was the larvae swimming around freely without touching the mussel. Larvae were active and were able to control their movements. Mussels were filtering throughout the experiment, and larvae appeared unaffected by the inhalant or exhalant currents generated by the mussels (Figure 9a). Larvae were even seen entering and leaving the inhalant siphon without any reaction from the mussel. However, when larvae touched the mussel's mantle, the latter closed immediately but without the mussel closing its shell. This behaviour was observed on several occasions (27% of the observations). In such situations, the larva quickly swam away (Figure 9b). On a few occasions (5% of the observations), the larvae were seen touching the mussel's shell without any reaction from the mussel. On two occasions (1% of the observations), a larva was imprisoned for a few seconds in the mussel's mantle, but was able to escape afterwards. In the first case, the larva entered head first into the mussel's inhalant siphon. The mantle immediately closed on the first half of the larva, preventing the larva from escaping. After 2 seconds, the mantle opened again, and the larva immediately escaped by rapid abdominal flexes (Figure 9d). In the second case, a larva touched the mussel's mantle with its abdomen. Again, the mantle immediately closed and the larva remained imprisoned during a fraction of a second. The larva escaped as soon as the mantle opened again. On one occasion (< 1% of the observations), we saw a larva entering the mussel, but we did not see it leave, neither through the inhalant nor the exhalant siphons. In this case, the larva swam very weakly and erratically. It then fell on the mussel's mantle, which closed immediately. The head remained visible for two seconds but the larva disappeared into the mussel thereafter

(Figure 9e). This last observation was made at the end of the experiment, when all larvae showed signs of weakness.

In the second series of observations, which was done over a 30-minute period with mussels from the Magdalen Islands, 174 interactions were noted between the lobster larvae and a mussel. As with the first series of observations, the most frequent behaviours were (a) larvae swimming around freely without touching the mussel (74%), (b) the larva touching the mussel's mantle followed by the mantle closing and the larva swimming away from the mussel (18%), (c) the larva touching the mussel's shell without any reaction from the mussel (7%) (Figure 10). On one occasion (<1%), a larva was imprisoned in the mussel but was able to escape afterwards. The larva swam very little and when it came close to the inhalant siphon, it appears to have been drawn in by the mussel. The mantle and the shell closed completely. After 10 seconds, the mussel opened slowly, and the larva moved about on the mantle, but the mantle closed again on the larva before it could escape. After a few seconds, the mantle opened again, and the larva succeeded in escaping. The larva was lethargic and sank a few centimetres before swimming again. Finally, one larva disappeared in the inhalant siphon of the mussel (<1%). Even though the larva was swimming, it did not seem to control its movements as well as the other larvae. It entered backwards into the inhalant siphon. The mantle closed for only a short moment but we did not see the larva leave by either the inhalant or the exhalant siphons. This last observation was made at the end of the experiment, when the larvae were showing signs of weakness.

Although the observations were limited to only two mussels, the nature and frequency of the different behaviours observed during the course of these two series of observations reflected what had been observed earlier in the beakers.

(a)



(b)

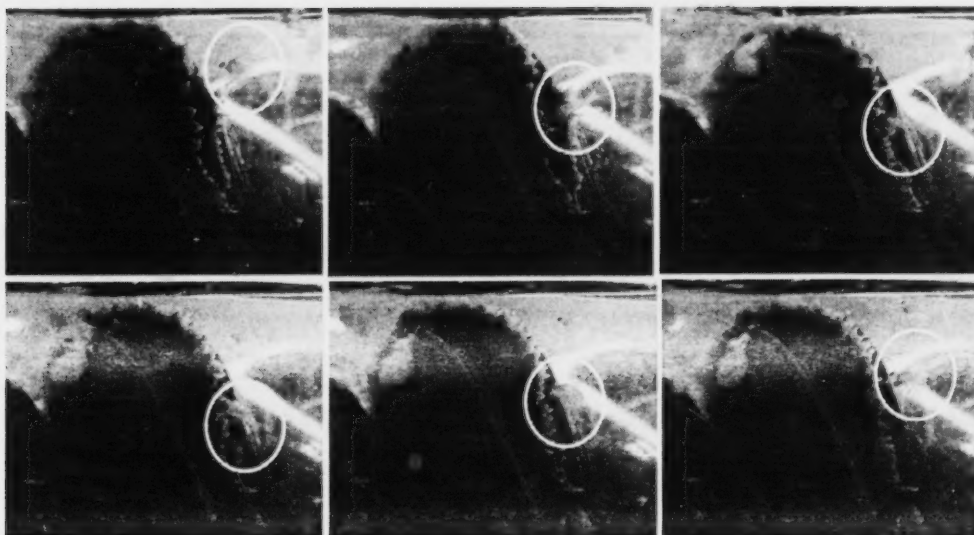


(c)



Figure 9. Types of behaviour observed between lobster larvae and mussels: (a) larvae swimming around freely without touching the mussel, (b) the larva touching the mussel's mantle followed by the mantle closing and the larva quickly swimming away from the mussel, and (c) the larva touching the mussel's shell without any reaction from the mussel. The images in (a) and (b) show a mussel from the Magdalen Islands while the image in (c) shows a mussel from Carleton.

(d)



(e)

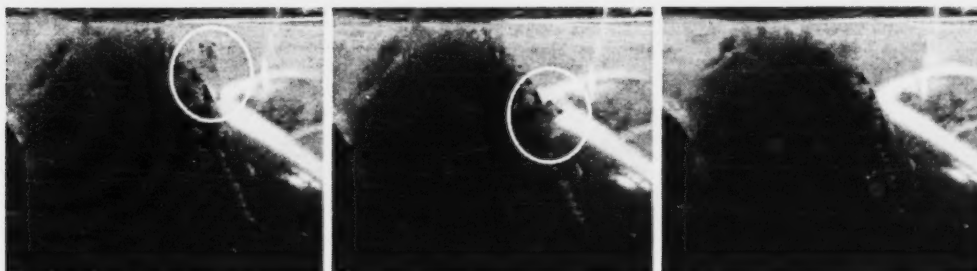


Figure 9 (continued). Types of behaviour observed between lobster larvae and mussels: (d) the larva touching the mussel's mantle, being trapped in it and then escaping once the mussel re-opens, and (e) contact, capture, and disappearance of the larva. The images in (d) et (e) show a mussel from Carleton.

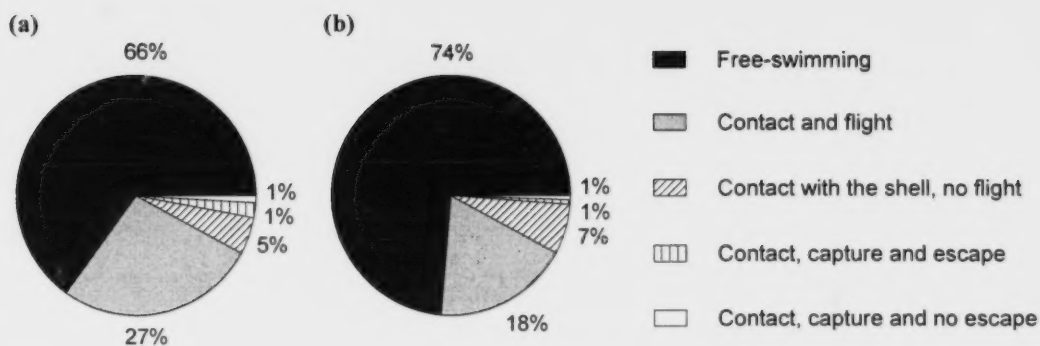


Figure 10. Frequency of each type of behaviour observed between lobster larvae and mussels in (a) series 1 (mussels from Carleton), and (b) series 2 (mussels from the Magdalen Islands). A total of 166 interactions were observed in the first series and 174 interactions in the second series.

4.0 DISCUSSION AND CONCLUSION

The results of this study indicate that mussels very seldom ingested lobster larvae and, if this occurred, they probably only ingested weakened larvae. This result is not surprising given the mobility and size of lobster larvae. In fact, the stage I larvae are already very mobile from the moment they are released. Though slower and less agile than at the postlarval stage (stage IV), stage I larvae can nevertheless move forwards, backwards, and up and down using the exopodite of their pereopods, and their third pair of maxillipeds. The larva is also able to move backwards very quickly by abruptly flexing its abdomen (see review by Ennis 1995). In contrast to Davenport *et al.* (2000), who found that *Artemia* sp. and copepods were unable to escape from the inhalant current once they were entrained by it, our video images showed that lobster larvae were not drawn in by the inhalant current created by mussels. They tended to avoid the current, but when they entered it, they were easily able to escape its influence. Ennis (1986) showed that in 46-74% of cases, stages I to III larvae could swim 5 minutes in a $2 \text{ cm}\cdot\text{sec}^{-1}$ current. The velocity of the inhalant current of a 2 cm mussel is about 0.1 to $0.6 \text{ cm}\cdot\text{sec}^{-1}$, according to a study by Green *et al.* (2003). In spite of the fact that the larger mussels used in this study likely generated stronger currents, larvae were observed to swim through the currents with ease on several occasions and sometimes even swam in and out of the mussel's inhalant siphon. Lobster larvae seemed in very good control of their movements around the mussel, and the mussel did not appear to be disturbed, as long as no contact occurred with their mantle. When larvae touched the edge of the mantle, it closed immediately. Usually, this reaction prevented the larva from entering the mussel, especially as the larva's reaction was to escape by vigorously flexing its abdomen. A similar escape response has also been reported for copepods by Davenport *et al.* (2000). It should be noted that no differences were observed in the behaviour of mussels from different sources.

There were however five occasions where larvae remained imprisoned in the mussel's inhalant siphon when it closed. In three cases out of five, larvae escaped. However, contrary to the observations of Davenport *et al.* (2000), our video images showed that larvae were generally not coated with mucus, nor inhaled again when the mussel reopened. In the other two cases in the present study, however, larvae disappeared in the inhalant siphon, and even though the mussel reopened, they were not observed again. It is important to note that these two observations were made at the end of the experiments. At this time, larvae showed obvious signs of slowing down and swam less. When a larva ceases to beat its appendages, it starts to sink (Herrick 1895). It is possible that the larvae simply sank inside the mussel. This could explain why some larvae were not found at the end of the series 1, 3, and 4 of experiment 2. The cause of this slowing down remains unknown. Our calculations suggest that it is not due to the accumulation of nitrogen waste products produced by the mussels. Based on work by Hawkins *et al.* (1983, 1985, 1986), the estimated concentration of NH_4 in the beakers was around 100 times inferior to the concentration that is harmful to stage I larvae (Young-Lai *et al.* 1991). Although magnetic stirrers were used in the experiments to ensure water mixing, it is possible that oxygen levels may have reached low levels and caused this deceleration.

Unfortunately, no direct measurements of oxygen concentration were made to allow us to verify this hypothesis.

Davenport *et al.* (2000) noted that mussels can be somewhat carnivorous and occasionally ingest large (3-6 mm) organisms. However, the frequency at which such organisms are found in the stomach contents of mussels (30-35 mm) in that study was only 0.8%. Although Lehane and Davenport (2002) also found mesozooplankton >3 mm in mussels measuring between 1.6 and 6.1 cm, the average length of the prey ranged mainly between 450 and 600 μm . Thus, it may be expected that the occurrence of lobster larvae in mussels is probably rather low, given that they are more than an order of magnitude larger than the organisms generally found in the stomachs of mussels.

Although the mobility of the stage I lobster larvae is sufficient to counter the currents induced by the filtration activity of mussels, this may not be the case for marine currents. The horizontal distribution of stage I larvae is largely dependent on surface currents, and there is thus a possibility that lobster larvae are passively advected to mussel farms. In some areas, the farming facilities may occupy large surfaces, increasing the probability of contact between mussels and lobster larvae. Moreover, depending on local commercial harvesting strategies, the sleeves are likely to contain mussels of a rather large size (>50 mm) when larvae appear in the water column. In the Magdalen Islands, lobster larvae begin to appear in the first days of July and are very abundant during the first two weeks of the month (Hudon *et al.* 1986, Ouellet *et al.* 2001). The release of stage I larvae continues until the end August, but they are less abundant at this time.

Although the area in which lobster larvae are distributed may overlap with the area where mussel farms are located, the probability that larva and mussels will come into contact is rather small because of their vertical distribution. Stage I larvae do not occupy all the water column, and remain most of the time concentrated near the surface, at a depth of approximately 1-2 meters. Stage I larvae migrate on a daily basis and are concentrated near the surface (0-0.8 m) at dawn and dusk. They are uniformly distributed between 0 and 1.6 m during the day and up to 2.4 m at night (Hudon *et al.* 1986). This preference for surface water is even stronger for stage II, III, and IV larvae (Hudon *et al.* 1986). This behaviour could confer lobster larvae some protection against farmed mussels. In Quebec, mussel farming is done using sleeves suspended from floating lines (longlines), the latter of which are generally at a depth of 1-2 m below the surface during the summer (Lagier 2001). In the Magdalen Islands, sleeves are suspended at depths greater than 2 meters (C. W. McKindsey, personal observations). Moreover, the sleeves are generally spaced 0.75 m to 1.0 m apart, and the longlines 20 m to 30 m apart (Lagier 2001), leaving sufficient space for the larvae to move.

The mobility, size and behaviour of stage I lobster larvae make it a very improbable prey for farmed mussels. During our experiments, no apparently vigorous larvae were ingested by mussels, in spite of the forced close proximity of the two species. Only seemingly weakened larvae were ingested by mussels, and these in very small

number. According to our observations, nothing indicates that the ingestion of lobster larvae by mussels in aquaculture sites can constitute a danger to lobster populations.

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